STUDY OF ATMOSPHERIC DISPERSION UNDER LOW WIND CONDITIONS IN AN URBAN ENVIRONMENT, FIRST RESULTS

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CONTEXT

- Modification of turbulence properties and dispersion mechanisms in low wind conditions (< 2 m/s) leads to stagnation of pollutants near the source (low transport and low diffusion), or on the contrary to a larger lateral dispersion (meandering)
- Difficulty in modeling due to the lack of data, especially for the urban environment, and incompatibility of existing theories with low wind conditions

➡ Large uncertainties in the calculations of the impact of atmospheric releases

OBJECTIVES

- Acquisition of experimental data on the dispersion of a tracer gas in urban environment under low wind conditions
- Analysis of experimental data to understand the mechanisms of dispersion in these conditions
- Comparison of experimental data to the first simulations obtained from a CFD model (code_saturne)

METHODS

MEASUREMENT CAMPAIGN

- Dispersion of Helium (He) as tracer gas in low wind conditions (14 releases in 2020)
- Measurement of He concentrations by air sampling and using mass spectrometers in real time
- Acquisition of He concentrations and turbulence measurements in the near field (< 300 m)

ANALYSIS

- Atmospheric Transfer Coefficients (ATC) and wind direction analysis
- Spectral and autocorrelation analysis of wind velocity components

$$R(\tau) = \exp(-p\tau)\cos(q\tau)$$ (Frenkiel, 1953)

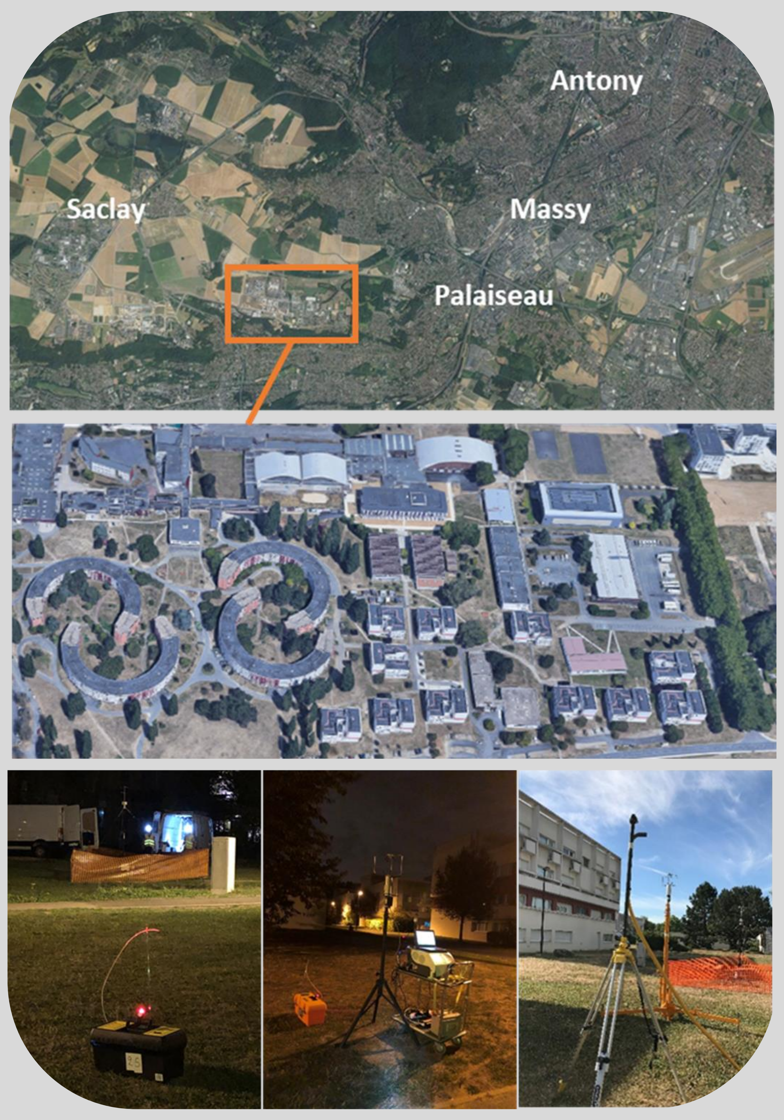
R : Autocorrelation function adjustment
τ : time lag (s)
p : parameter related to the turbulence time scale (s^{-1})
q : parameter associated with the oscillation time scale (s^{-1})

- The meandering period T(s) :

$$T = \frac{2\pi}{q}$$ (Mortarini et al., 2016)

MODELLING

- Stationary simulation : constant boundary conditions
- Pseudo stationary simulation : combination of several stationary simulations. Boundary conditions are determined by using different inlet wind directions representative of the variation of this parameter during the air sampling period



EQUIPEMENT

STUDY AREA

Instrumental Site for Research by Atmospheric Remote Sensing (SIRTA), Ecole Polytechnique, Palaiseau

EXPERIMENTAL EQUIPEMENT

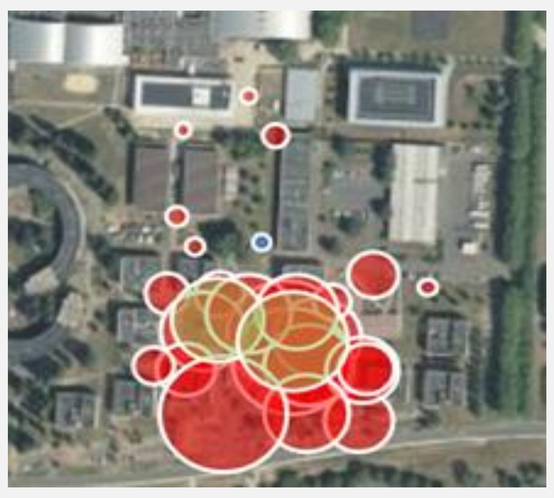
- Tracer gas: He
- 29 air samplers
- Helium analyzers : 3 mass spectrometers (1 fixed and 2 mobiles)
- Ultrasonic anemometers (frequency 10 Hz) on a mast at 3 different heights (5 m, 10 m and 30 m), and at several points in the built environment (at 3 m)
- 1 meteorological station
- 1 LIDAR and 1 SODAR
- 1 laboratory truck

COMPUTATIONAL EQUIPEMENT

- **code_saturne:** Open source CFD (Computational Fluid Dynamics) code developed by EDF-R&D and CEREA (Code_Saturne 7.1 Theory Guide, 2021)
- Using of the atmospheric module
- Operating on HPC machine (High Performance Computing)
- Mesh size: 2400 m x 1600 m x 300 m with 13 million cells

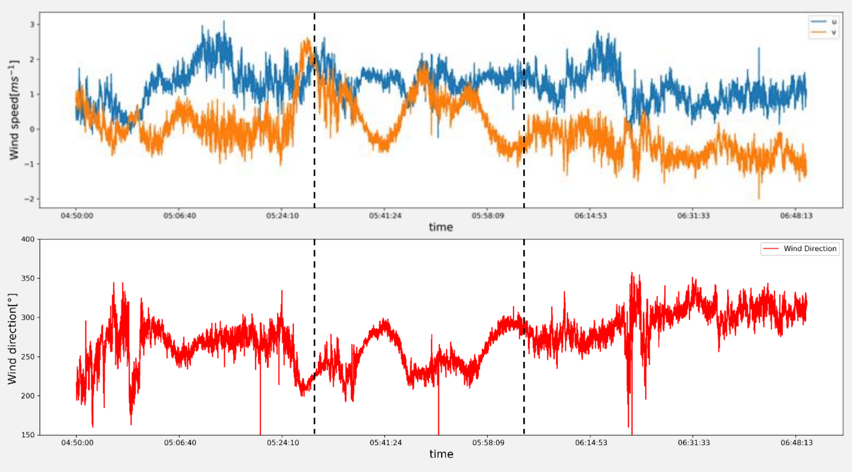
FIRST RESULTS : STUDY OF RELEASE 14 (11/09/2020 between 4:50 and 6:50)

EXPERIMENT



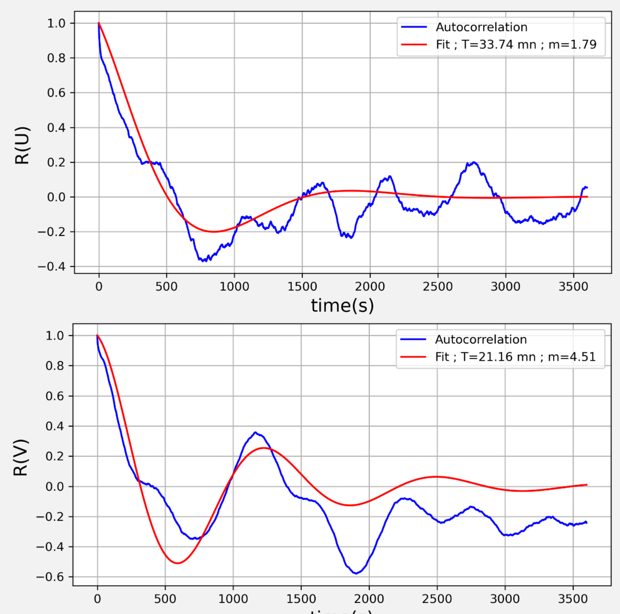
He plume dispersion based on ATC distribution. Wind speed 1.4 $m.s^{-1}$ at 30 m
Emission point
ATC at sampling point
ATC at real time
The bubbles size is proportional to the ATC

- The He plume disperses south of the emission point with higher values of ATC due to the predominant northern wind
- The lateral dispersion of the plume is favored



Horizontal wind-velocity components u and v (top), wind direction (bottom). Black lines refer to the period of Helium emission (between 5:35 and 06:05)

- Oscillation of wind direction and velocity components characterize the meandering phenomenon
- The Period of wind direction is about 20 mn
- The Period of the lateral wind component V is about 20 mn. The period of the longitudinal wind component U is less defined

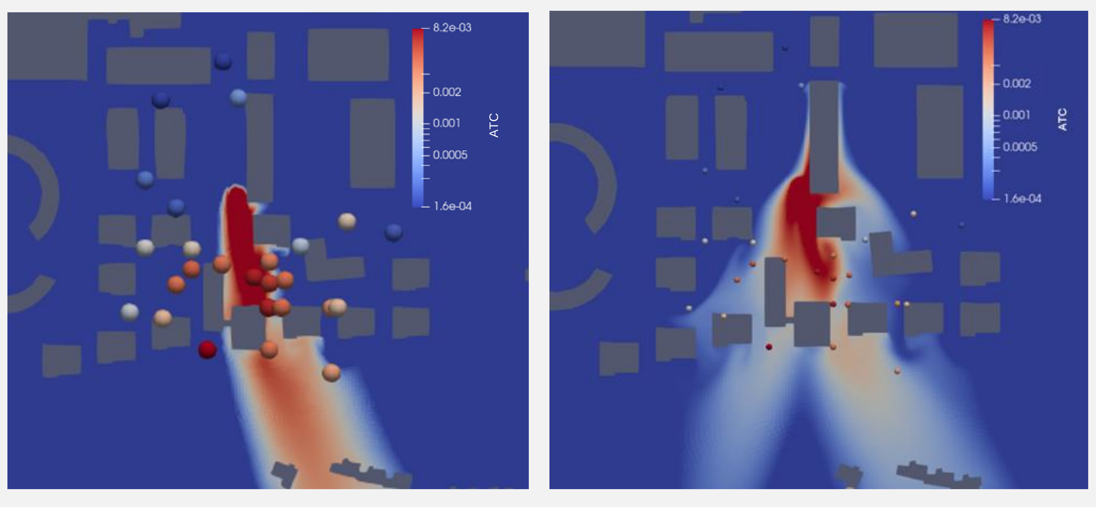


Autocorrelation function for the horizontal wind velocity components u (on the top) and v (on the bottom). m is the ratio between q and p, it represents a decisive parameter to define the meandering

Component U : meandering period is 33 mn
Component V : meandering period is 21 mn

The meandering is more marked on the v component than the u component which is consistent with the time series

MODELLING



Two simulations of the plume dispersion for the release 14. Stationary case (on the left) and pseudo stationary case (on the right). Measured concentrations are indicated by coloured dots

- **Stationary simulation** : the plume does not reach some measurements locations where He was detected. The model lowers the lateral plume dispersion compared to the measurements
- **Pseudo stationary simulation :** takes better into account the time variation of the wind direction and thus better models the horizontal dispersion

CONCLUSION AND OUTLOOK

- Meandering is observed by analysing wind direction and velocity components of release 14 performed on 11 september 2020. It caused the lateral spread of He plume in low wind conditions. Meandering has also been characterized in other releases of campaign 2020 which were not presented in this study. Its period varies from one release to another and could reach 1 hour. Future measurement campaign is planned in 2022 to enrich the database, analyse and define more cases of this specific phenomenon
- CFD model lowers the lateral dispersion in stationary simulation compared to the measurements. Considering the variation of wind direction gives more representative results of the plume dispersion. In future work, tests will be performed on the turbulence model and other methods to take into account the flow unsteadiness as well as adapting the Monin-Obukhov theory to low wind speed conditions

MEMBRE DE ETSON

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